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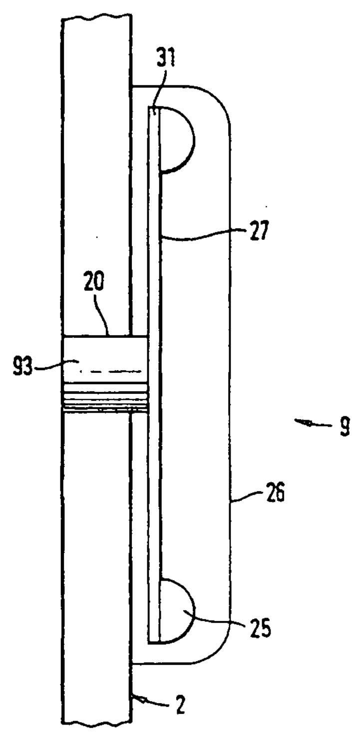
(54) Title: INERTIAL VIBRATION TRANSDUCERS

(57) Abstract

An inertial vibration transducer (9) characterised by a plate-like piezo-electric bender (27) and means (20, 93) adapted to mount the bender on a member (2) to be vibrated, the arrangement being such that a substantial part of the bender is spaced from the member for movement relative thereto.



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INERTIAL VIBRATION TRANSDUCERS

DESCRIPTION

TECHNICAL FIELD

The invention relates to transducers and more particularly to vibration transducers for loudspeakers comprising panel-form acoustic radiating elements.

BACKGROUND ART

It is known from GB-A-2262861 to suggest a panel-form loudspeaker comprising:-

a resonant multi-mode radiator element being a unitary sandwich panel formed of two skins of material with a spacing core of transverse cellular construction, wherein the panel is such as to have ratio of bending stiffness (B), in all orientations, to the cube power of panel mass per unit surface area (μ) of at least 10;

a mounting means which supports the panel or attaches

to it a supporting body, in a free undamped manner;

and an electro-mechanical drive means coupled to the panel which serves to excite a multi-modal resonance in the radiator panel in response to an electrical input within a working frequency band for the loudspeaker.

DISCLOSURE OF INVENTION

Embodiments of the present invention use members of nature, structure and configuration achievable generally and/or specifically by implementing teachings of our co-pending PCT application no. (our case P.5711) of even date herewith. Such members thus have capability to sustain and propagate input vibrational energy by bending waves in operative area(s) extending transversely of thickness often but not necessarily to edges of the member(s); are configured with or without anisotropy of bending stiffness to have resonant mode vibration components distributed over said area(s) beneficially for acoustic coupling with ambient air; and have predetermined preferential locations or sites within said area for transducer means, particularly operationally active or moving part(s) thereof effective in relation to acoustic vibrational activity in said area(s) and signals, usually electrical, corresponding to acoustic content of such vibrational activity. Uses are envisaged in co-pending International application No. (our file P.5711) of even date herewith for such members as or in "passive" acoustic devices without transducer means, such as for reverberation or for acoustic filtering or for acoustically "voicing" a space or room; and as or in

"active" acoustic devices with transducer means, such as in a remarkably wide range of sources of sound or loudspeakers when supplied with input signals to be converted to said sound, or in such as microphones when exposed to sound to be converted into other signals.

This invention is particularly concerned with active acoustic devices in the form of loudspeakers.

Members as above are herein called distributed mode acoustic radiators and are intended to be characterised as in the above PCT application and/or otherwise as specifically provided herein.

The present invention provides an inertial vibration transducer characterised by a plate-like piezo-electric bender and means adapted to mount the bender on a member to be vibrated, the arrangement being such that a substantial part of the bender is spaced from the member for movement relative thereto. A mass may be secured to the said substantial part of the bender.

The bender may be of crystalline form. The bender may be disc-like, the mounting means may be disposed centrally thereof, and the mass may be secured to the periphery of the bender. Alternatively the peripheral margin of the disc-like bender may be fixed to the member, and the mass may be secured to the centre of the bender.

A resilient member may be employed to attach the mass to the bender.

Benders as described above may be attached to opposite sides of the member to be vibrated and coupled together by

a common mass to operate in push/pull mode.

From another aspect the invention is a loudspeaker having a distributed mode acoustic radiator, characterised by a transducer as described above coupled to vibrate the radiator.

BRIEF DESCRIPTION OF DRAWINGS

The invention is diagrammatically illustrated, by way of example, in the accompanying drawings, in which:-

Figure 1 is a diagram showing a distributed-mode loudspeaker as described and claimed in our co-pending International application No. (our case P.5711);

Figure 2a is a partial section on the line A-A of Figure 1;

Figure 2b is an enlarged cross-section through a distributed mode radiator of the kind shown in Figure 2a and showing two alternative constructions;

Figure 3 is a diagram of a first embodiment of transducer;

Figure 4 is a diagram of a second embodiment of transducer, and

Figure 5 is a diagram of a third embodiment of transducer.

BEST MODES FOR CARRYING OUT THE INVENTION

Referring to Figure 1 of the drawings, there is shown a panel-form loudspeaker (81) of the kind described and claimed in our co-pending International application No. (our case P.5711) of even date herewith comprising a rectangular frame (1) carrying a resilient suspension (3)

round its inner periphery which supports a distributed mode sound radiating panel (2). A transducer (9) e.g as described in detail with reference to our co-pending International applications Nos. (our cases P.5683/4/5) of even date herewith, is mounted wholly and exclusively on or in the panel (2) at a predetermined location defined by dimensions x and y, the position of which location is calculated as described in our co-pending International application No. (our case P.5711) of even date herewith, to launch bending waves into the panel to cause the panel to resonate to radiate an acoustic output.

The transducer (9) is driven by a signal amplifier (10), e.g. an audio amplifier, connected to the transducer by conductors (28). Amplifier loading and power requirements can be entirely normal, similar to conventional cone type speakers, sensitivity being of the order of 86 - 88dB/watt under room loaded conditions. Amplifier load impedance is largely resistive at 6 ohms, power handling 20-80 watts. Where the panel core and/or skins are of metal, they may be made to act as a heat sink for the transducer to remove heat from the motor coil of the transducer and thus improve power handling.

Figures 2a and 2b are partial typical cross-sections through the loudspeaker (81) of Figure 1. Figure 2a shows that the frame (1), surround (3) and panel (2) are connected together by respective adhesive-bonded joints (20). Suitable materials for the frame include lightweight framing, e.g. picture framing of extruded metal e.g.

aluminium alloy or plastics. Suitable surround materials include resilient materials such as foam rubber and foam plastics. Suitable adhesives for the joints (20) include epoxy, acrylic and cyano-acrylate etc. adhesives.

Figure 2b illustrates, to an enlarged scale, that the panel (2) is a rigid lightweight panel having a core (22) e.g. of a rigid plastics foam (97) e.g. cross linked polyvinylchloride or a cellular matrix (98) i.e. a honeycomb matrix of metal foil, plastics or the like, with the cells extending transversely to the plane of the panel, and enclosed by opposed skins (21) e.g. of paper, card, plastics or metal foil or sheet. Where the skins are of plastics, they may be reinforced with fibres e.g. of carbon, glass, Kevlar (RTM) or the like in a manner known per se to increase their modulus.

Envisaged skin layer materials and reinforcements thus include carbon, glass, Kevlar (RTM), Nomex (RTM) i.e. aramid etc. fibres in various lays and weaves, as well as paper, bonded paper laminates, melamine, and various synthetic plastics films of high modulus, such as Mylar (RTM), Kaptan (RTM), polycarbonate, phenolic, polyester or related plastics, and fibre reinforced plastics, etc. and metal sheet or foil. Investigation of the Vectra grade of liquid crystal polymer thermoplastics shows that they may be useful for the injection moulding of ultra thin skins or shells of smaller size, say up to around 30cm diameter. This material self forms an orientated crystal structure in the direction of injection, a preferred orientation for the

good propagation of treble energy from the driving point to the panel perimeter.

Additional such moulding for this and other thermoplastics allows for the mould tooling to carry location and registration features such as grooves or rings for the accurate location of transducer parts e.g. the motor coil, and the magnet suspension. Additional with some weaker core materials it is calculated that it would be advantageous to increase the skin thickness locally e.g. in an area or annulus up to 150% of the transducer diameter, to reinforce that area and beneficially couple vibration energy into the panel. High frequency response will be improved with the softer foam materials by this means.

Envisaged core layer materials include fabricated honeycombs or corrugations of aluminium alloy sheet or foil, or Kevlar (RTM), Nomex (RTM), plain or bonded papers, and various synthetic plastics films, as well as expanded or foamed plastics or pulp materials, even aerogel metals if of suitably low density. Some suitable core layer materials effectively exhibit usable self-skinning in their manufacture and/or otherwise have enough inherent stiffness for use without lamination between skin layers. A high performance cellular core material is known under the trade name 'Rohacell' which may be suitable as a radiator panel and which is without skins. In practical terms, the aim is for an overall lightness and stiffness suited to a particular purpose, specifically including optimising

contributions from core and skin layers and transitions between them.

Several of the preferred formulations for the panel employ metal and metal alloy skins, or alternatively a carbon fibre reinforcement. Both of these, and also designs with an alloy Aerogel or metal honeycomb core, will have substantial radio frequency screening properties which should be important in several EMC applications. Conventional panel or cone type speakers have no inherent EMC screening capability.

In addition the preferred form of piezo and electro dynamic transducers have negligible electromagnetic radiation or stray magnet fields. Conventional speakers have a large magnetic field, up to 1 metre distant unless specific compensation counter measures are taken.

Where it is important to maintain the screening in an application, electrical connection can be made to the conductive parts of an appropriate DML panel or an electrically conductive foam or similar interface may be used for the edge mounting.

The suspension (3) may damp the edges of the panel (2) to prevent excessive edge movement of the panel. Additionally or alternatively, further damping may be applied, e.g. as patches, bonded to the panel in selected positions to damp excessive movement to distribute resonance equally over the panel. The patches may be of bitumen-based material, as commonly used in conventional loudspeaker enclosures or may be of a resilient or rigid

polymeric sheet material. Some materials, notably paper and card, and some cores may be self-damping. Where desired, the damping may be increased in the construction of the panels by employing resiliently setting, rather than rigid setting adhesives.

Effective said selective damping includes specific application to the panel including its sheet material of means permanently associated therewith. Edges and corners can be particularly significant for dominant and less dispersed low frequency vibration modes of panels hereof. Edge-wise fixing of damping means can usefully lead to a panel with its said sheet material fully framed, though their corners can often be relatively free, say for desired extension to lower frequency operation. Attachment can be by adhesive or self-adhesive materials. Other forms of useful damping, particularly in terms of more subtle effects and/or mid- and higher frequencies can be by way of suitable mass or masses affixed to the sheet material at predetermined effective medial localised positions of said area.

An acoustic panel as described above is bi-directional. The sound energy from the back is not strongly phase related to that from the front. Consequently there is the benefit of overall summation of acoustic power in the room, sound energy of uniform frequency distribution, reduced reflective and standing wave effects and with the advantage of superior reproduction of the natural space and ambience in the

reproduced sound recordings.

While the radiation from the acoustic panel is largely non-directional, the percentage of phase related information increases off axis. For improved focus for the phantom stereo image, placement of the speakers, like pictures, at the usual standing person height, confers the benefit of a moderate off-axis placement for the normally seated listener optimising the stereo effect. Likewise the triangular left/right geometry with respect to the listener provides a further angular component. Good stereo is thus obtainable.

There is a further advantage for a group of listeners compared with conventional speaker reproduction. The intrinsically dispersed nature of acoustic panel sound radiation gives it a sound volume which does not obey the inverse square law for distance for an equivalent point source. Because the intensity fall-off with distance is much less than predicted by inverse square law then consequently for off-centre and poorly placed listeners the intensity field for the panel speaker promotes a superior stereo effect compared to conventional speakers. This is because the off-centre placed listener does not suffer the doubled problem due to proximity to the nearer speaker; firstly the excessive increase in loudness from the nearer speaker, and then the corresponding decrease in loudness from the further loudspeaker.

There is also the advantage of a flat, lightweight panel-form speaker, visually attractive, of good sound

quality and requiring only one transducer and no crossover for a full range sound from each panel diaphragm.

Figure 3 illustrates an embodiment of piezo-electric transducer (9) in which a crystalline disc-like piezo bender (27) is mounted at its centre on one end of a lightweight rigid cylindrical block (93) of rigid foam plastics which is rigidly fixed in an aperture (20) in a distributed mode radiator panel (2) e.g. by means of an adhesive, the said one end of the block (28) projecting from the face of the panel (2) so that the periphery (31) of the bender (27) is freely suspended adjacent to a face of the panel (2). An annular ring (25) of plastics, e.g. mineral loaded polyvinylchloride is rigidly fixed to the periphery of the piezo bender (27) to add mass to the free periphery of the piezo bender. Thus when the transducer is energized with an acoustic signal, the piezo bender (27) vibrates and due to its mass launches bending waves into the panel (2) to cause the panel to resonate and produce and radiate an acoustic output. The transducer (9) may be covered by a domed housing (26) which is fixed to the panel (2) to protect the transducer.

The piezo-electric transducer (9) of Figure 4 comprises a disc-like piezo bender (27) fixedly mounted by its periphery (31) on the surface of a panel (2) e.g. with the aid of an adhesive, with the central portion of the bender (27) freely suspended over a cavity (29) in the panel (2) such that only the periphery (31) of the bender (27) is in contact with the panel. A mass (25) e.g. of

plastics material is attached to the centre of the bender (27) with the interposition of a damping pad (30) of resilient material, e.g. of an elastic polymer.

Thus an acoustic signal applied to the piezo bender will cause the bender to vibrate and thus to launch bending waves into the panel. The drive effect of the transducer is enhanced by loading the driver (27) with the mass (25) to increase its inertia.

The transducer arrangement (9) of Figure 5 is similar to that of Figure 4 except that in this embodiment a pair of piezo benders (27) are attached on opposite sides of a cavity (29) through a panel (2) to operate in push/pull mode. In this arrangement, the centres of both benders (27) are connected together by a common mass (25) with resilient damping pads (30) positioned between each bender (27) and the mass (25).

INDUSTRIAL APPLICABILITY

The transducers of the invention are relatively simply in construction and are effective in use.

CLAIMS

1. An inertial vibration transducer characterised by a plate-like piezo-electric bender and means adapted to mount the bender on a member to be vibrated, the arrangement being such that a substantial part of the bender is spaced from the member for movement relative thereto.

2. An inertial vibration transducer according to claim 1, characterised by a mass secured to the said substantial part of the bender.

3. An inertial vibration transducer according to claim 2, characterised in that the bender is plate-like, in that the mounting means is disposed centrally thereof, and in that the mass is secured to the periphery of the bender.

4. An inertial vibration transducer according to claim 2, characterised in that the bender is plate-like, in that the peripheral margin thereof is fixed to the member, and in that the mass is secured to the centre of the bender.

5. An inertial vibration transducer according to claim 4, characterised by a resilient member by which the mass is mounted on the bender.

6. An inertial vibration transducer according to claim 5, characterised by benders attached to opposite sides of the member to be vibrated and coupled together by a common mass to operate in push/pull mode.

7. An inertial vibration transducer according to any preceding claim, characterised in that the piezo-electric bender is of crystalline form.

8. A loudspeaker having a distributed mode acoustic

radiator, characterised by a transducer as claimed in any preceding claim coupled to vibrate the radiator to cause it to resonate.

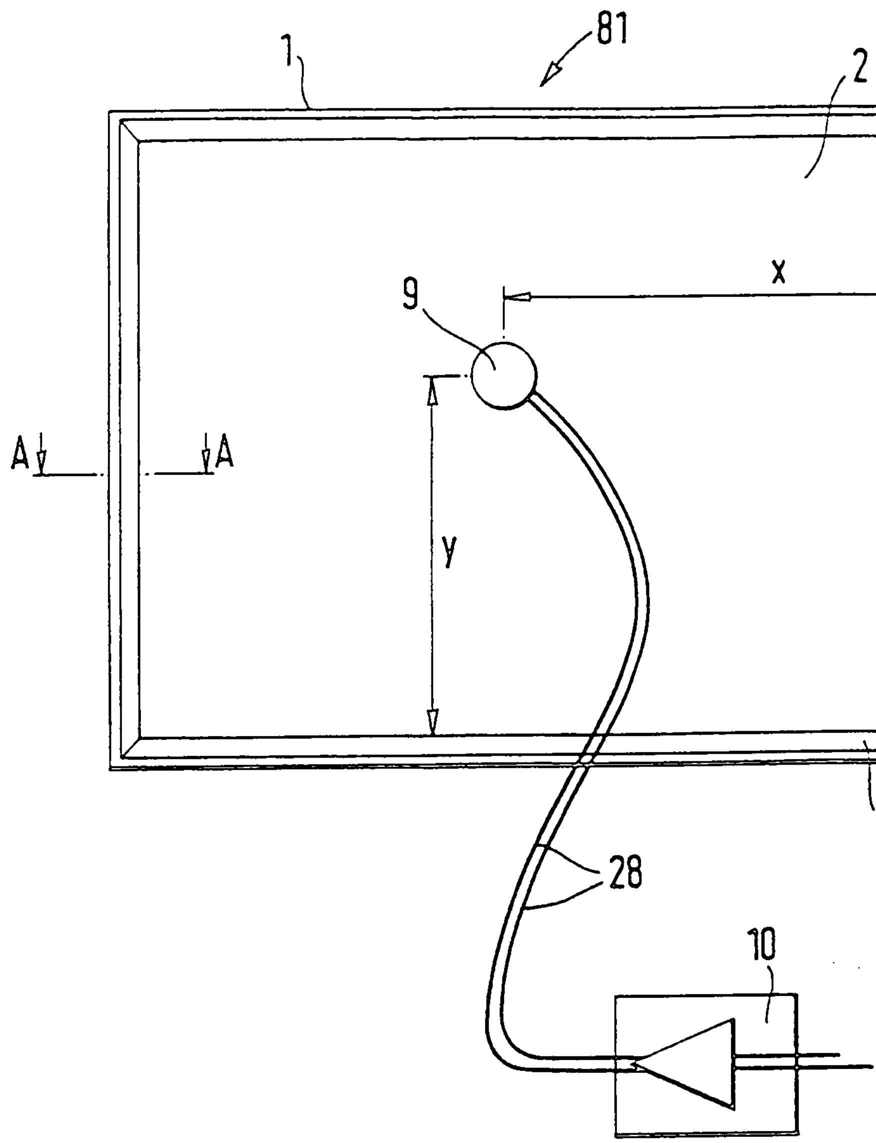

Fig. 1

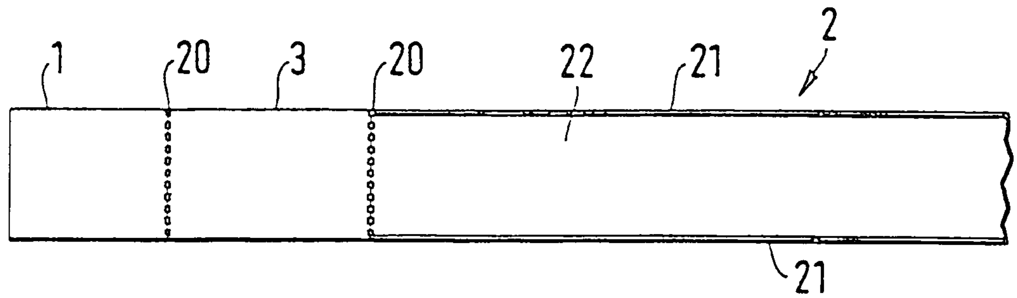

Fig. 2a

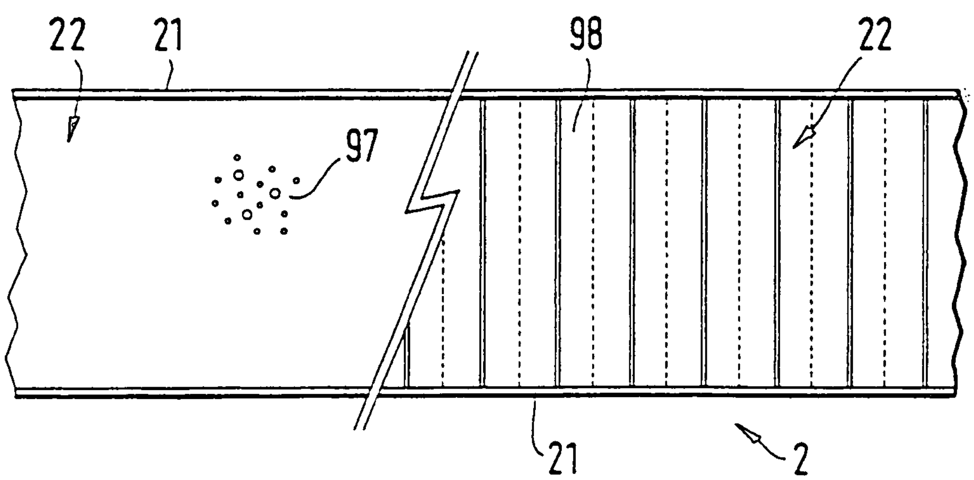

Fig. 2b

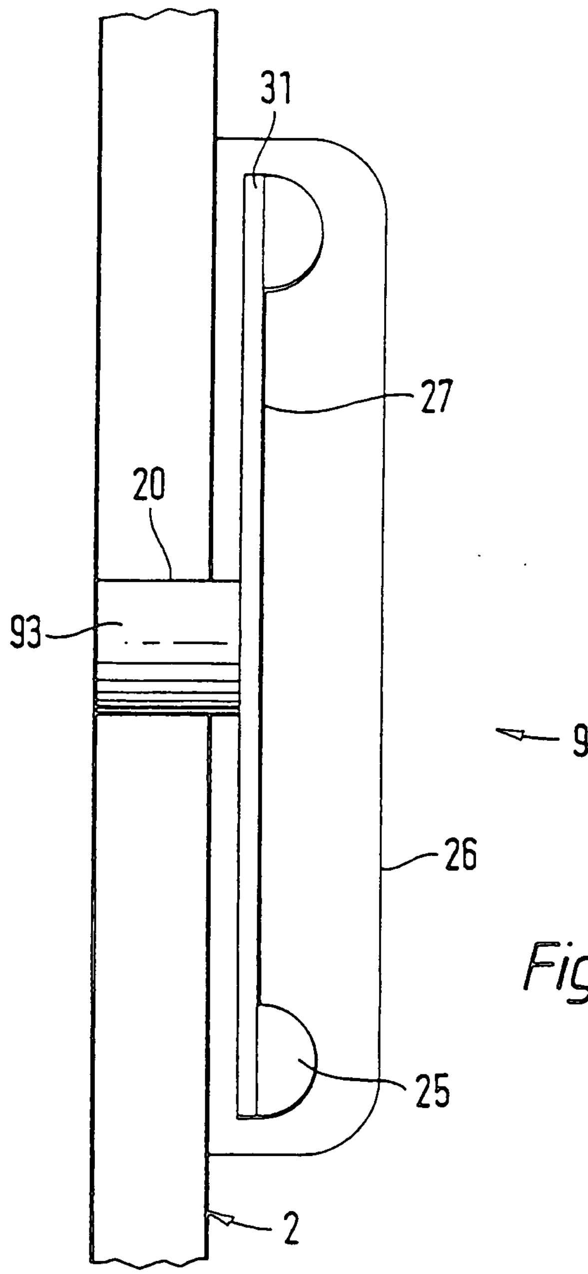

Fig.3

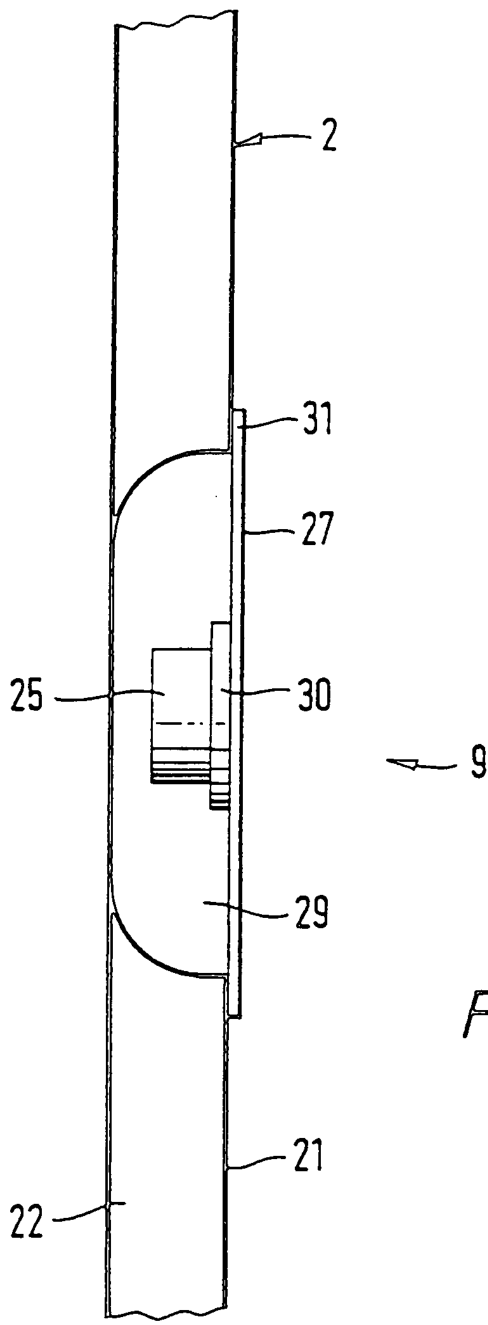

Fig. 4

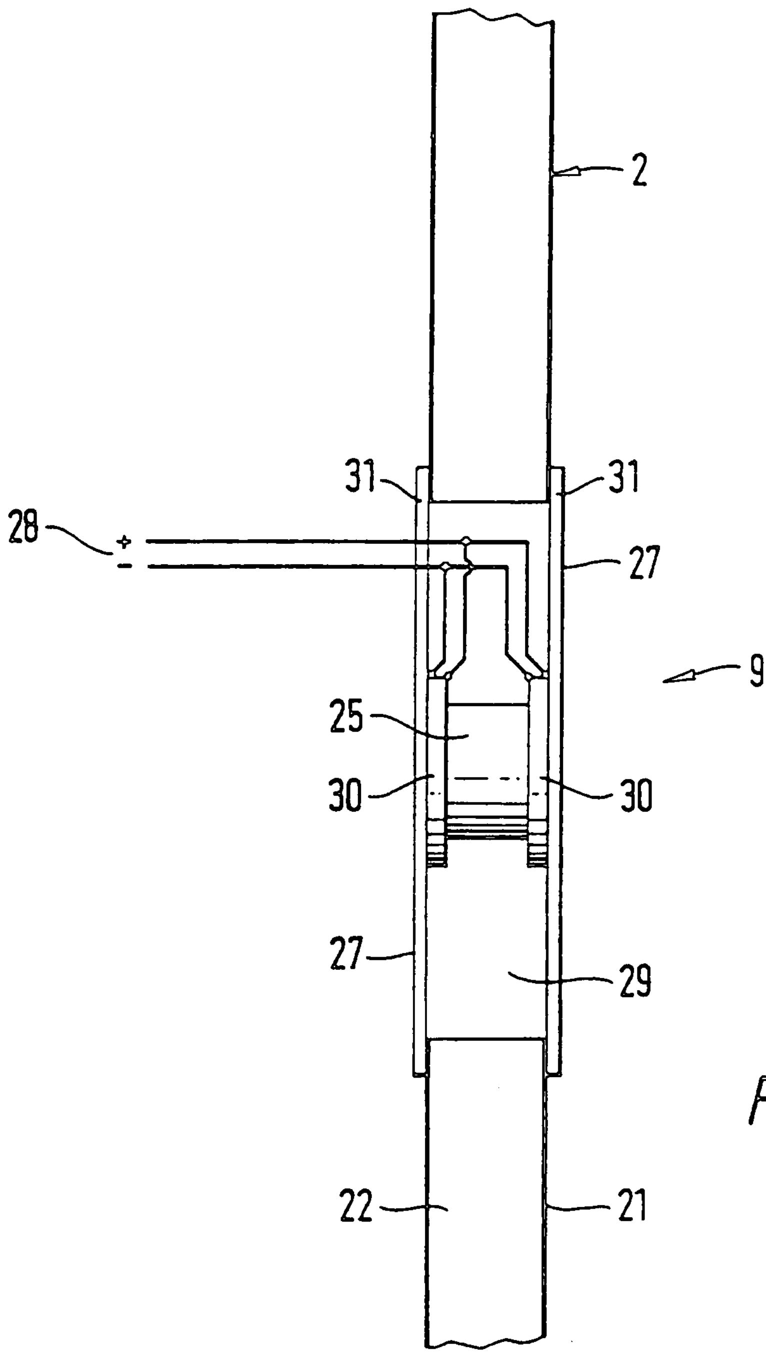

Fig.5

INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04R17/00 H04R7/06 H04R1/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	GB 2 219 712 A (MURATA MANUFACTURING CO) 13 December 1989 see page 10, line 8 - line 17; figure 5 ---	1,8
A	WO 92 03024 A (SECR DEFENCE BRIT) 20 February 1992	1
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
17 December 1996	13.01.97

Name and mailing address of the ISA	Authorized officer
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2

INTERNATIONAL SEARCH REPORT

Information on patent family members

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